Coastal Ocean Modeling & Dynamics

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LONG-TERM GOALS

The long-terms goals of this research are to improve our ability to understand and predict environmental conditions in the coastal ocean.

OBJECTIVES

The central objective of the proposed research is to explore problems in coastal ocean modeling and dynamics, including Lagrangian trajectory analysis and the various roles played in coastal ocean predictability by basic physical elements of coastal ocean circulation. The research is being conducted by a graduate student, in collaboration with the PI.

APPROACH

The central activity of the proposed research will be the development and analysis of a set of high-resolution numerical simulations of the Oregon coastal ocean that will extend the recent work of Rivas and Samelson (2009), Kim et al. (2009), Kim et al. (2010), and Springer et al. (2009). The simulations and analysis will be carried out by the GRA, Rodrigo Duran, who passed the COAS physical oceanography Ph.D. qualifying exam in July 2009, and is currently in his second year of graduate course work. The proposed research focuses primarily on two complementary aspects of the coastal circulation: predictability and Lagrangian motion.

With regard to the Lagrangian motion problem, the basic idea of the proposed research is to extend the calculations of Rivas and Samelson (2009) by using simulated tracer techniques, and to explore the sensitivity of the results to changes in physical parameterizations and numerical representations. Rivas and Samelson (2009) used backward integration of resolved-velocity-field trajectories to obtain information on Lagrangian motion and cross-shelf exchange in the coastal upwelling regime. The first step in the proposed research will be to use, instead, forward integrations of simulated tracer fields, in order to obtain complementary and potentially more complete information on fluid parcel motion. Such techniques have been used successfully in some previous coastal simulations (e.g., Kuebel Cervantes et al., 2004; Springer et al., 2009) and offer the promise of a more complete representation and visualization of the complex patterns of Lagrangian motion in the coastal zone. On the other hand,

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the complexity of the Lagrangian motion – particularly on the long-term, seasonal timescales considered by Rivas and Samelson (2009) – presents challenges for the required inversion of the tracer fields. A second scientific goal of the tracer simulations is to understand and quantify the significance of small-scale mixing on the content of advected water parcels, and to use these direct simulations to explore and quantify the downstream effects of upstream changes in water properties that are implied by the ideal Lagrangian calculations of Rivas and Samelson (2009).

With regard to the predictability problem, the basic idea of the proposed research is to extend the calculations of Kim et al. (2009), Springer et al. (2009), and Kim et al. (2010) to analyze quantitatively the dynamical processes that cause the differences in predictability in different geographical regimes that were found in those studies. The general physical picture that is implied by these previous studies is that, to first order, the flow over the shelf responds in a largely deterministic manner to the imposed wind forcing, while the flow over the slope and farther offshore evolves primarily through the development of internal instabilities (Fig. 1).

We propose to extend these initial results on the contrasting dynamical regime and to analyze the dynamics of the associated processes in detail. In addition to direct diagnosis of the simulated circulation dynamics, other analysis techniques to be explored include the computation of quantities such as Lyapunov vectors and exponents (e.g., Wolfe and Samelson, 2007), and other appropriate measures that can be used to distinguish between stable, deterministic behavior, and unstable, non-deterministic behavior.

WORK COMPLETED

Several sets of simulations for year 2005, with various different density-compensated modifications of temperature and salinity in various different source regions, and with advection of various combinations of passive tracers, have been completed and analyzed. Some initial month-long simulations with three passively-advected Lagrangian label fields have also been completed. In principle, these provide a complete description of the Lagrangian motion field during the period of simulation (Kuebel Cervantes et al., 2004).

RESULTS

The results of the analysis provide independent support for the particle-tracking conclusions regarding the locations of upwelling source waters, as the modified temperature and salinity properties are detectable downstream, in the upwelling region (Figs. 1,2). The results further indicate that along-path mixing has a substantial influence on the amplitude of the temperature and salinity response in the upwelling region, relative to the amplitude of the imposed upstream changes (Fig. 2). These results supplement similar results described in the report for the grant “Ensemble Methods for Coastal Ocean Flows” (N00014-08-1-0563), of which the present grant is the continuation.

IMPACT/APPLICATIONS

The results have impact and application for understanding of biological and any other related Lagrangian processes in the coastal zone, including dispersal of passive floating or submerged objects, and development of extreme biological conditions such as hypoxia or anoxia.

RELATED PROJECTS

The present grant is the continuation of the grant “Ensemble Methods for Coastal Ocean Flows” (N00014-08-1-0563).

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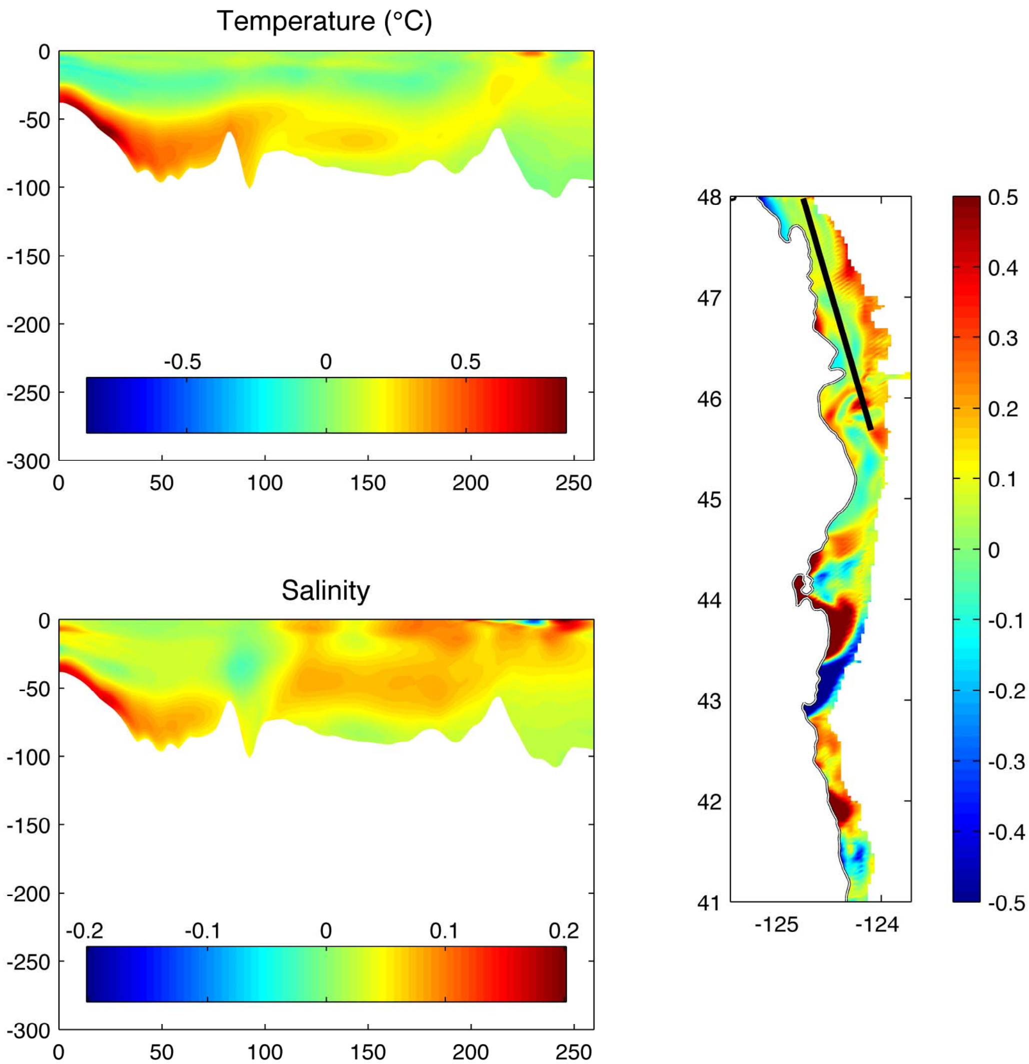

Figure 1. Temperature (^{o}C) and salinity (psu) differences along the Oregon shelf from the control simulation during August 2005, for a simulation with modified, density-compensated, temperature and salinity at the northern upwelling source region identified through particle-tracking by Rivas and Samelson (2010). Southward propagation along the shelf and upwelling of the modified fluid is evident in the vertically averaged temperature difference (right panel; offshore boundary of contoured region is at 200-m isobath) and the sections of temperature (upper left) and salinity (lower left) difference along the indicated line (solid line, right panel).

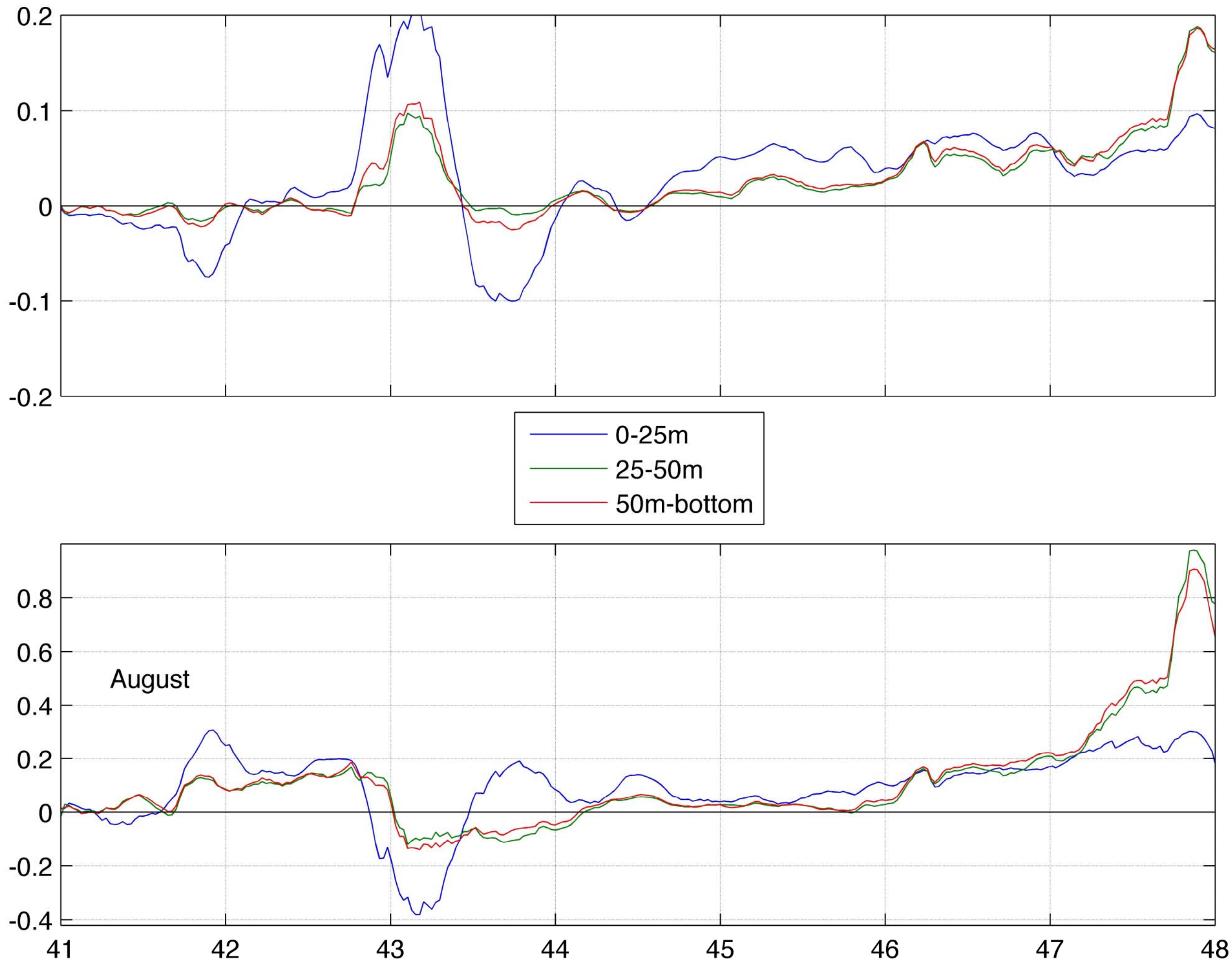

Figure 2. Response functions for temperature (^{o}C, lower panel) and salinity (psu, upper panel) differences vs. latitude (^{o}N) along the Oregon shelf from the control simulation during August 2005, for a simulation with modified, density-compensated, temperature and salinity at the northern upwelling source region identified through particle-tracking by Rivas and Samelson (2010). The response functions show the time-, cross-shore, and depth-averaged temperature and salinity differences from the coast to the 200-m isobath at each latitude, for the three indicated depth intervals (0-25 m, 25-50 m, 50 m – bottom). The differences north of Cape Blanco (43 ^{o}N) show characteristic responses in the upwelling zone over the shelf of 5% to 10% of the upstream modifications in temperature and salinity, respectively, indicating substantial along-path mixing but also a significant, measurable, downstream signal in the upwelling zone. There is a transition from bottom-intensified to surface-intensified response around 46 ^{o}N - 47 ^{o}N, consistent with upwelling of the deep source fluid. Near Cape Blanco and farther south, the northern source region has less influence, and a large eddy signal dominates the response in this simulation.